PENNSTATE ARL

iMAST

Institute for Manufacturing and Sustainment Technologies

A U.S. Navy Manufacturing Technology Center of Excellence

QUARTERLY 2002 No.1

Achievement Awards for Technical Support Presented

ARL's Kenneth C. Meinert and Jay F. Tressler were recently recognized by the Commander of the Naval Undersea Warfare Center Division, Keyport (Washington) for their outstanding technical support relative to Navy ManTech Project S0869 (Torpedo Repair). Citations were awarded in recognition for "…outstanding technical performance in the development of a laser-based repair technology for thermally sensitive materials and components associated with Navy undersea weapon systems." The citation further notes "Your development, testing, qualification, and implementation of this process (via the Navy Manufacturing Technology Program) for repair purposes, has direct application to the MK48 ADCAP Torpedo, MK30 Target, and many other potential applications. Your contribution to a laser-based repair technology for the Navy will undoubtedly result in considerable economic benefits to the Navy in the future. This unique repair technology will benefit this command and the U.S. Navy by providing a wide range of repair options that will reduce costs while enhancing operational readiness throughout the Fleet."

Ken Meinert and Jay Tressler pause for a photo following the award of their technical support citation from NSWC Keyport by Mr. Tom Tesch and Mr. Steve Linder. From left to right: Mr. Bob Cook, director of iMAST; Jay Tressler; Dr. Ray Hettche, ARL director; Ken Meinert; Mr. Steve Linder, director, Navy ManTech Program, ONR; and Mr. Tom Tesch, director, Navy Industrial and Corporate Program Department, ONR.

Many components used today in Navy platforms are fabricated from materials that are heat-treated to attain the properties required for specific desired areas within the platform. Challenging wear and corrosion issues identified by the Naval Undersea Warfare Center Division at Keyport were brought to the attention of iMAST. iMAST investigators traveled to Keyport to evaluate the challenge. A viable in-situ solution and implementation plan was identified by ARL Penn State's iMAST team. The Keyport-iMAST team then submitted an issue to the Navy ManTech Program office. The issue was selected and subsequently funded as a Navy ManTech project.

Due to the wide range of use this capability provides, there are a number of additional applications which will focus specifically on aluminum structural repairs. These additional applications will conceivably support both air and ground combat vehicles also.

This Navy ManTech project has extended the life of a current Navy system by providing manufacturing technologies which support the maintenance, repair, and overhaul of Navy and Marine Corps weapon systems. That capability is particularly unique to iMAST's repair technology effort at ARL Penn State. It is a unique capability we encourage you to further investigate.

For more information on laser-based repair efforts on-going at ARL Penn State, contact Ken Meinert at (814) 863-7281 or <kcm104@psu.edu>. For more information on NUWC Keyport's repair effort, contact Michael Lehman at (360) 396-7173 or <mlehman@kpu.nuwc.navy.mil>.

Focus On Environmental Technologies

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**
4. TITLE AND SUBTITLE **iMAST Quarterly, 2002 Number 1**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Penn State University,Applied Research Laboratory,Institute for Manufacturing and Sustainment Technologies,State College,PA,16804**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

PENNSTATE

iMAST

Applied Research Laboratory
Institute for Manufacturing and Sustainment Technologies

DIRECTOR
Robert B. Cook
(814) 863-3880 rbc5@psu.edu

MATERIALS PROCESSING and DRIVETRAIN TECHNOLOGIES
Maurice F. Amateau, Ph.D.
(814) 863-4481 mfa1@psu.edu

LASER PROCESSING TECHNOLOGIES
Richard P. Martukanitz, Ph.D.
(814) 863-7282 rxm44@psu.edu

ADVANCED COMPOSITES MATERIALS TECHNOLOGIES
Kevin L. Koudela, Ph.D.
(814) 863-4351 klk121@psu.edu

MANUFACTURING SYSTEMS TECHNOLOGIES
Mark T. Traband, Ph.D.
(814) 865-3608 mtt1@psu.edu

NAVY/MARINE CORPS REPAIR TECHNOLOGIES
Sean L. Krieger
(814) 863-0896 slk22@psu.edu

iMAST ADMINISTRATOR and EDITOR
Gregory J. Johnson
(814) 865-8207 gjj1@psu.edu

STAFF ASSISTANT
Lori L. Mowery
(814) 865-3264 llm1@psu.edu

WORLD WIDE WEB
www.arl.psu.edu/areas/imast/imast.html

NAVY PROGRAM MANAGER
James G. Mattern
(202) 781-0737
matternjg@navsea.navy.mil

IN THIS QUARTERLY

EDITOR'S CORNER

Getting the Word Out

I would like to thank our readers for the feedback we've received from time to time, relative to our publication. Our director, Bob Cook, and I encourage you to challenge us at every opportunity. The responses you provide allow us to get the right words out about the Navy ManTech Program.

As the Office of Naval Research continues to fine-tune the Navy ManTech program, it is important that our outreach remains open and clear. This publication is one of many forums undertaken to help facilitate a strong partnership between government, industry and academia.

Why is that important? It is critical that we ensure the affordability of viable weapon systems under development for the Navy and Marine Corps, in order to properly support our forward deployed forces who go into harm's way. Good technology transferred into the Fleet provides a force multiplier effect which saves lives and fosters national defense. While there is no substitute for the standard issue Sailor or Marine, we can provide the necessary tools of war that will provide protection for them on the land, in the air, and at sea.

Visit the Office of Naval Research web site. Check the link to the various Centers of Excellence that comprise the Navy ManTech Program. If you have any questions, give us a call. If we can't answer your questions, we'll put you in touch with someone who can. Communication is the key to success for almost any program. Pass this newsletter around. Better yet, send us the address of those you think will profit from the material we publish.

Greg Johnson

PENNSTATE iMAST

MATERIALS PROCESSING TECHNOLOGIES

MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES

LASER PROCESSING TECHNOLOGIES

ADVANCED COMPOSITES MATERIALS TECHNOLOGIES

NAVY/MARINE CORPS REPAIR TECHNOLOGIES

MANUFACTURING SYSTEMS TECHNOLOGIES

Focus on Environmental Technologies

Coatings Removal Research

by Janice M. Schneider, John J. Merenich, and Edward W. Reutzel

Abstract

Department of Navy maintenance and repair facilities are in a seemingly unending search for new and better techniques and methodologies for the removal of coatings from vehicles, vessels, and aircraft. As environmental protection and occupational health regulations change, as coatings formulations are revised, and as manpower and funding levels fluctuate, old coatings removal processes become unsuitable or obsolete and new processes must be found. Three distinctly different coatings removal techniques—chemical paint stripping, induction heating and laser paint removal—have been studied under iMAST and REPTECH programs. Each of these techniques has its own unique set of advantages, disadvantages and possibilities, and each is another component of a toolbox of potential coatings removal techniques for Navy maintenance and repair personnel to consider.

Introduction

Three coatings removal techniques with the potential to increase worked safety and to reduce hazardous emissions are currently under various stages of evaluation at The Applied Research Laboratory at The Pennsylvania State University.

- New chemical paint strippers have been evaluated for paint removal during vehicle maintenance and repair at the Marine Corps Logistics Base in Albany, Georgia. One commercially available material outperformed all others in the test and is being evaluated further.
- Laser-based paint removal has been shown to remove paint in a number of different ways, depending on the process variables used. It is possible, by controlling these variables, to precisely remove paint in individual coating layers.
- Induction heating heats a metal surface in seconds to soften the paint and allow rapid scraping of the paint from the vessel.

This article presents an overview of these techniques and projects.

Chemical Paint Strippers

A collaborative project between ARL and the Marine Corps Logistics Base (MCLB) in Albany, Georgia was approved and funded under the MANTECH Repair Technology Program (REPTECH). The goal of this project was to identify an environmentally friendly and safe chemical paint stripper that would effectively and efficiently remove the wide variety of coatings encountered in the maintenance of Marine Corps vehicles and components.

The effectiveness of six chemical paint strippers was evaluated for four types of coatings commonly encountered during routine maintenance and repair at the MCLB.

The six stripping solutions evaluated were hydrogen peroxide at designated concentrations, four commercial strippers from TURCO, and one commercial stripper from OAKITE.

The Albany Marine Corps Logistics Base depot supplied the painted samples for the purpose of this evaluation. Four types of coatings were included: seafoam green epoxy, epoxy powder coat, two different samples of solvent-based CARC and two different samples of water-based CARC. In some cases 2" × 6" metal panels were prepared with the coatings, while in other cases actual vehicle parts were received and cut into sizes suitable for testing.

The paint samples were placed in bottles with the designated stripper; these were placed in a shaker bath and agitated at the designated temperature. After initial screening tests at 150°F, tests were conducted at room temperature, typically evaluating samples at 5 hours and 24 hours. The amount of paint removed on each side of the part was estimated by visual inspection, then averaged and reported as the overall percent removed.

After an initial set of tests, four of the chemical strippers were totally removed from consideration. Two of these were for physical reasons—one stripper had a serious foaming problem

PROFILE

Janice Schneider is an Associate Research Engineer at the Applied Research Laboratory at Pennsylvania State University. Since 1993 she has been employed in the Environmental Technology Group, involved in environmental research studies and air and water analysis. She is currently supervisor of the Air and Water Quality Laboratory at ARL. Her recent projects include determination of the capture efficiency of a paint overspray shroud, studies on the photolytic degradation of volatile organic compounds, and development and testing of hand-held HAZMAT analyzers for paint analysis.

Ms. Schneider earned her B.S. in Chemistry from Purdue University and her M.S. in Chemistry at Fairleigh-Dickinson University. She has over twenty-five years of experience in analytical chemistry, particularly chromatography and spectroscopy. She can be reached at (814) 865-3536 or by e-mail at: <jms32@psu.edu>.

and another was very thick, not readily miscible with water, and difficult to wash off. The other two were removed for reasons of ineffectiveness.

The two remaining strippers, Oakite Q7900A and TURCO 6776 Thin, were subjected to additional tests to gather data on repeatability and on their ability to remove coatings from parts with complex geometries.

Under the conditions of this testing and with the four paint types provided for the test (2 solvent-borne and 2 water-borne CARC), the TURCO 6776 Thin stripper outperformed the Oakite Guardostrip 7900A stripper. It effectively stripped four of the six coating samples tested in 5 hours at room temperature (Figures 1 and 2). It effectively stripped the remaining two coating samples in under 2 hours at 150°F.

These findings have been communicated to the MCLB. The MCLB plans to follow-up with their own large-scale in-house studies on the TURCO 6776 Thin material.

Laser-based Removal

Laser-based paint stripping utilizes the unique properties of laser light in an advanced coating removal tool. The laser converts electrical energy to useful optical energy. The output from the laser is a beam of light that is coherent and monochromatic (one wavelength or color). The coherent property of the laser enables the beam to focus to very high power densities for such applications as cutting or welding. For paint stripping, these same properties allow the user to select a desired power density to selectively evaporate, incinerate, or

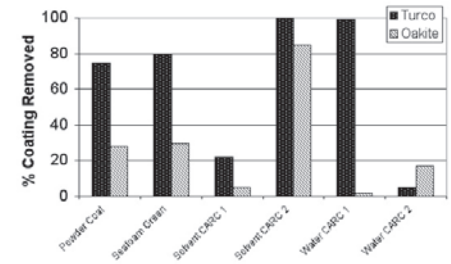


Figure 2. Comparison of Average Coating Removed for Two Chemical Strippers

mechanically ablate a coating without damaging the underlying surface. Since the process originates from the photon and material interaction, laser stripping is considered non-contact and non-impact.

To address the physics of the removal process, it is important to realize that laser radiation heats the surface of the coating and evaporation occurs. However, the magnitude of the irradiance and the adhesion strength of the coating affect the prevailing removal mechanism. High irradiances are defined as laser pulses with durations on the order of nanoseconds, and that are typically realized with Q-switched lasers.

If the coating is weakly adhering and the irradiance is high enough to result in a rapidly expanding plasma, the resultant shock wave may be strong enough to mechanically remove large particles of the coating through stress reflections at coating-coating and coating-substrate interfaces. If the coating exhibits weak adhesion and irradiance is low, the part will tend to heat up and the induced thermal stresses may result in cracking and flaking of the coating. If the coating is strongly adhering, then high irradiance will result in evaporation as the prevailing removal mechanism. Lower irradiance on a strongly adhering coating will result in thermal decomposition or burning of the coating. Figure 3 summarizes these conditions. Figure 4 offers yet another perspective.

Figure 5 illustrates the effects pulse parameters can have on the mode of ablation and the substrate. Spots 1–3 have been created with a pulsed laser with increasing pulse duration and fluence (energy/unit area). Although difficult to discern in black and white

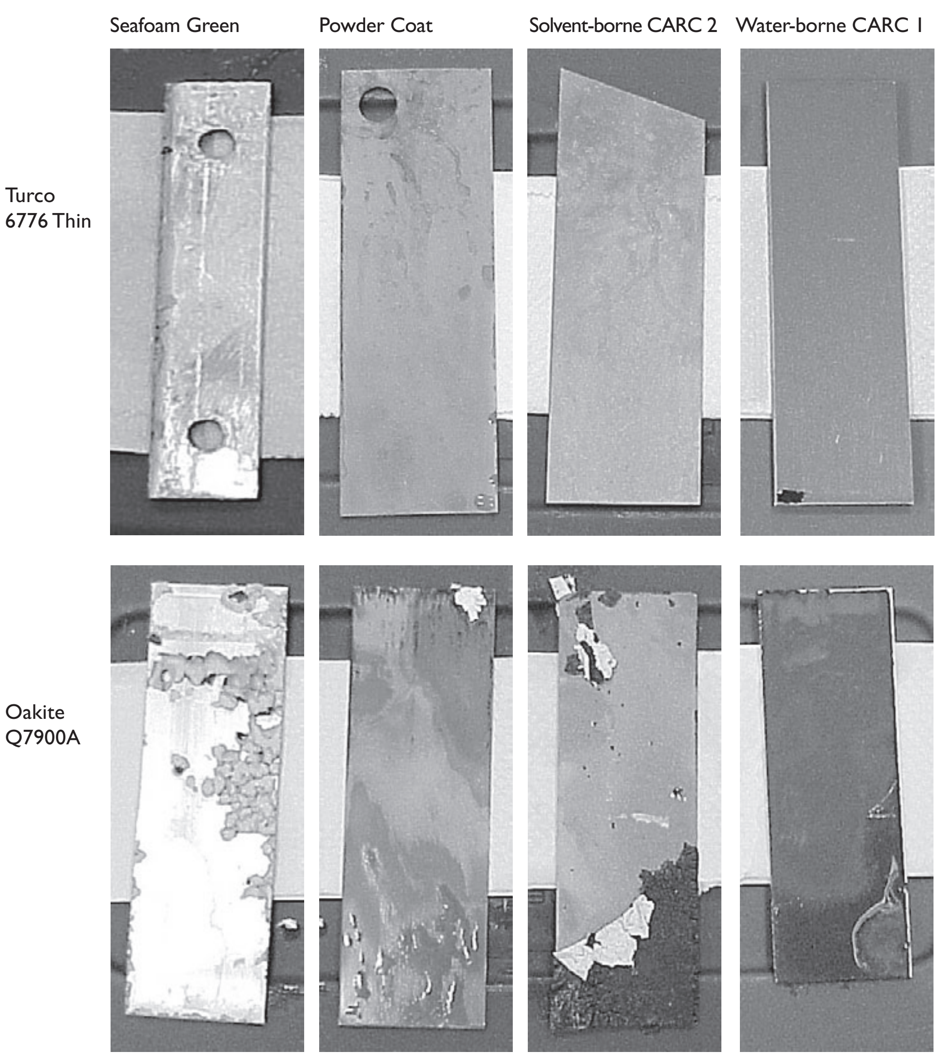


Figure 1. Comparison paint samples after five hours contact time at room temperature.

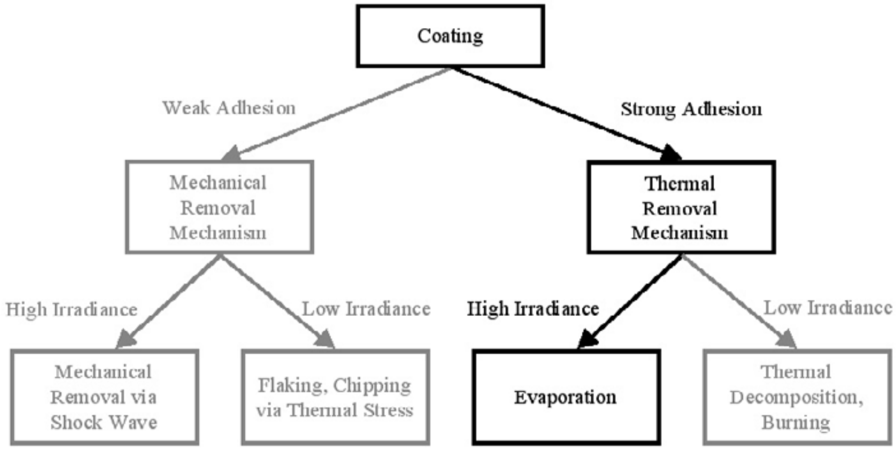


Figure 3. Mechanisms of laser-based coating removal.

photographs, the paint shows evidence of melting and is blackened around the edge of the hole, the substrate is covered with a tenacious soot, and in spot 3 the substrate has melted significantly and is damaged. Spot 4, created with a Q-switched laser, has much shorter pulse duration and much lower fluence and succeeded in removing the coating down to the substrate. No soot is present and the edges of the spot are crisp and well defined. It is interesting to note that although a Q-switched laser may seem the obvious choice for fast, clean coating removal, historically Q-switched lasers have not had the required pulse rate and high average power to achieve cleaning rates comparable with pulsed, or even continuous wave, lasers. The designer must weigh the benefits of fast and damaging coating removal to slower, cleaner, and less damaging coating removal. In recent work, several Q-switched lasers have been combined to increase processing rates.

A potentially significant benefit of laser based coating removal is the ability to very precisely remove individual coating layers. Figure 6 illustrates layer-by-layer coating removal realized with the Q-switched laser. The top area has only the white top coat removed, the second has the top and primer removed, and the third represents the bare substrate after complete coating removal. The fourth area shows all three layers removed in turn. Again, black and white photography may not fairly depict these different layers.

The laser-based coating removal technique is gaining industry acceptance, and several commercial vendors now offer complete systems. To reap the maximum benefit, the systems are often customized to meet the specific application. Laser based coating removal systems have been used in isolated cases in the aerospace industry for several years, and are currently being considered for use in stripping torpedo components and helicopter rotor blades during repair operations.

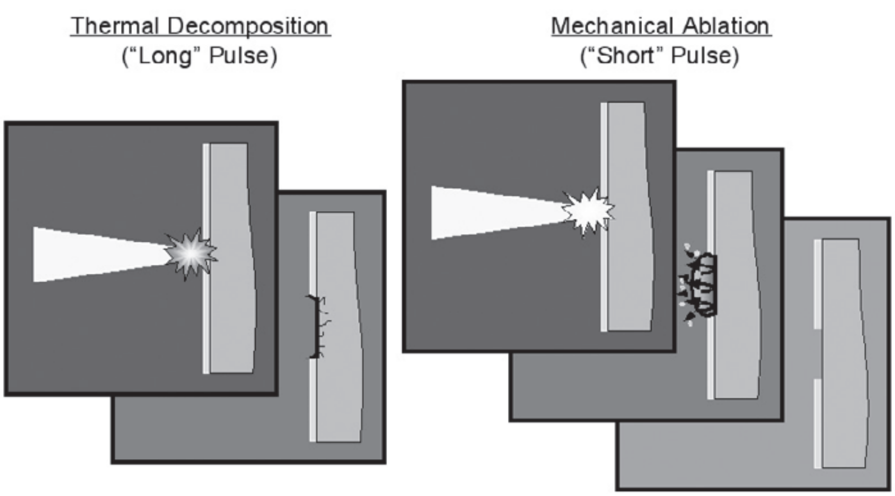


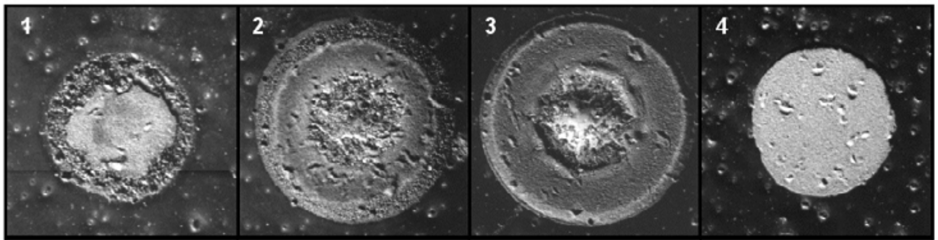
Figure 4. Removal mechanisms.

Induction Heating

The induction heating process is similar in concept to that of using a heat gun to soften the paint in residential and commercial applications. In both processes, heat is used to weaken the bond between the paint and the substrate. Once the bond is weakened, a mechanical method such as scraping is used to break the bond between the two materials and remove the paint from the substrate. Induction heating is different from using a heat gun in the method by which the heat is applied. For residential and commercial use the substrate is almost exclusively a wood or plaster related product, and the heating method is usually a heat gun which heats the surface of the paint by a combination of radiation, convection and conduction.

For induction heating the substrate must be metal. A high frequency alternating current is passed through a coil, creating an oscillating magnetic field around the coil. When the oscillating magnetic field is placed near the metal surface, it induces an eddy current in the metal in the surrounding area. The resistance of the metal to the induced current causes the metal to get hot. The rate of heating and the depth of the heated area are initially based on the current level and on the frequency of the alternating current, respectively. Over time, conduction will transfer the heat to a larger volume.

Ideally only the interface between the substrate and the coating has to be heated in order weaken the bond. Using higher power (current) creates a more powerful magnetic field thereby increasing the rate of heating and decreasing the time required to reach a desired temperature. Changing the frequency of the alternating current



1 millisecond	2 milliseconds	8 milliseconds	8 nanoseconds
4.1 joules	12.4 joules	39.7 joules	0.4 joules

Figure 5. Results from various pulse parameters.

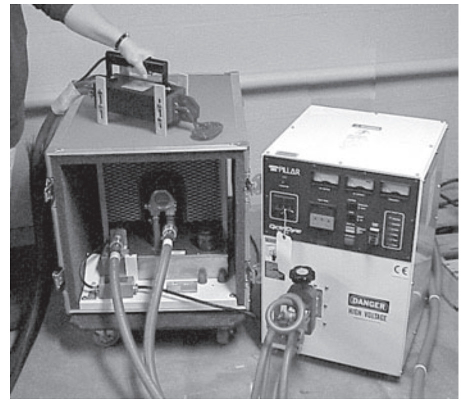


Figure 7. Induction heating equipment.

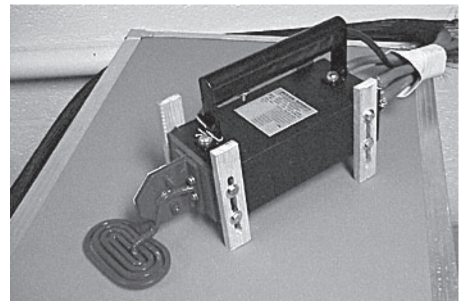


Figure 8. Close-up of portable induction heating head.

determines the penetration of the eddy currents and therefore the depth of the heating effect. That is, at higher frequencies, the affected substrate depth is shorter, resulting in shallower heat penetration. Since it is desirable to limit the heat to the substrate-coating interface, a higher frequency current is generally used.

Under a REPTECH sponsored project, a portable induction heating unit (Figures 7 and 8) was evaluated at ARL Penn State on various samples supplied by Puget Sound Naval Shipyard. Because the frequency of a given induction heating unit is fixed at the factory, a high frequency model was chosen for this application. Power level, distance from the coil to the surface to be heated, and time of heating are parameters which can be controlled at the point of use; these parameters were studied and optimized for application to the Puget Sound samples. To minimize the heating time the power level was maximized and the coil distance from the surface was minimized. However, the power is limited by costs, with higher power units being more expensive, and the minimum coil distance is limited by the fact that arcing will occur if the coil is positioned too close to the metal surface. With the unit used in this study, the high frequency cutoff shut the unit down when the coil-to-surface distance became too small. One additional consideration is that the minimum coil distance is also dictated by any surface irregularities that are present.

With the given induction unit and the chosen parameters, the desired temperatures were achieved in less than 15 seconds. Caution had to be used in the maximum temperatures that were reached. Temperatures that were too low would not provide enough softening of the paint for effective removal of the coating. Conversely, temperatures that were too high could result in off-gassing of hazardous materials in the coating. Parameters were selected to achieve an optimal temperature. A temperature control mechanism would have to be developed in order to consistently reach the desired setpoint temperature in a commercial unit selected for this application.

With the operational parameters established, the paint removal process was tested. The induction unit was used to heat the surface of the metal substrate. Following the heating operation the unit was removed and manual scraping was performed on the area immediately affected by the induction coil. The scraping operation easily removed most of the coating. However, because of the surface roughness, some sparse coating still remained within the cracks and crevices.

With the development of the operational parameters completed, the ongoing efforts at ARL Penn State include studies on the off-gassing characteristics of various coatings when heated by induction heating. These tests are being performed to determine whether there are any environmental or health and safety concerns related to induction heating of these coatings.

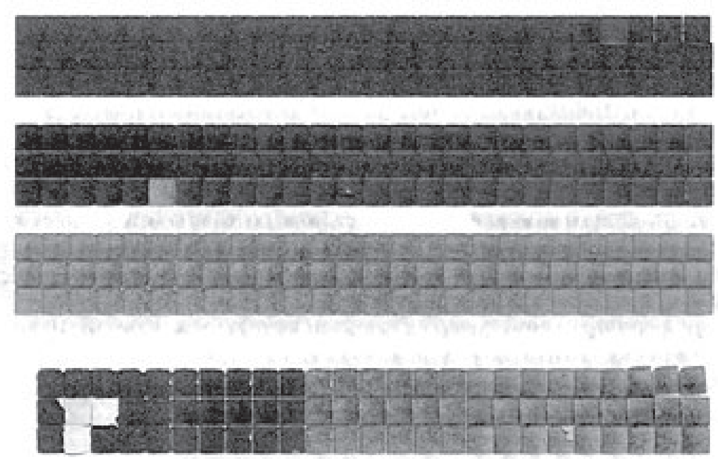


Figure 6. Layer-by-layer coating removal with the Q-switched laser.

Mr. Tom Tesch (left), director of Naval Industrial and Corporate Programs, ONR, and Mr. Tom Pyne (center), comptroller, ONR join iMAST Director, Bob Cook, at ARL Penn State's DMC 2001 exhibit booth.

iMAST Participates in DMC '01

Members of iMAST recently participated in the annual Defense Manufacturing Conference, held in Las Vegas, Nevada. Once again leaders from government, industry, and academia assembled to exchange perspectives and information relative to manufacturing technology and industrial modernization. The theme "A Manufacturing Odyssey," set the forum for discussions concerning the future of defense manufacturing and sustainment for both military and commercial products. The next annual conference is scheduled to be held in Dallas, Texas from 2–5 December, 2002.

LAV-25

Light Armored Vehicle Joins ARL

A Light Armored Vehicle has been delivered to the ARL Penn State by the U.S. Marine Corps on a temporary basis. The vehicle will be used to address manufacturing issues related to hull welding and also health usage monitoring of drive and other subsystems. ARL's laser processing department will evaluate the ballistic integrity of the hull while the CBM department instruments the vehicle for logistics planners and maintainers. The primary function of the LAV is to provide strategic mobility to reach and engage the threat, tactical mobility for effective use of fire power, fire power to defeat soft and armored targets, and battlefield survivability to carry out additional combat and scout missions. Features of the LAV include all-terrain and all-weather operations, with night capabilities. The vehicle is air transportable via C-130, C-141, C-5 and the CH-53E helicopter. When combat loaded, there are 210 ready rounds and 1420 stowed rounds 25mm ammunition as well as 400 ready rounds and 1,200 stowed rounds of 7.62mm. There are 8 ready rounds and 8 stowed rounds of smoke grenades. A supplementary M240E1 7.62mm machine gun can be printle-mounted at the commander's station in the turret. The LAV-25 is fully amphibious with a maximum of three minutes preparation. In addition to a crew of three, the vehicle can carry 6 Marines internally. The LAV is also produced in air defense and command and control variants. Weighing 28,200 pounds, the vehicle can reach land speeds of 62 mph on the road and 6 mph in the water. There are currently over 400 LAVs in the marine Corps' inventory.

MGen Kelly pauses in front of the Marine Corps Light Armored Vehicle on loan to ARL. From left to right: Dr. Karl Reichard, director, ARL Condition-Based Maintenance Department; Mr. Ed Crow, director, ARL Systems and Operations Automation Division; MGen Kelly; Colonel Stephen Fenstermacher, USMC, Chief, Logistics Information Systems Division, J-4; and Dr. Tom Donnellan, associate director, Materials and Manufacturing, ARL Penn State.

Vice Director Logistics (J-4) Visits iMAST

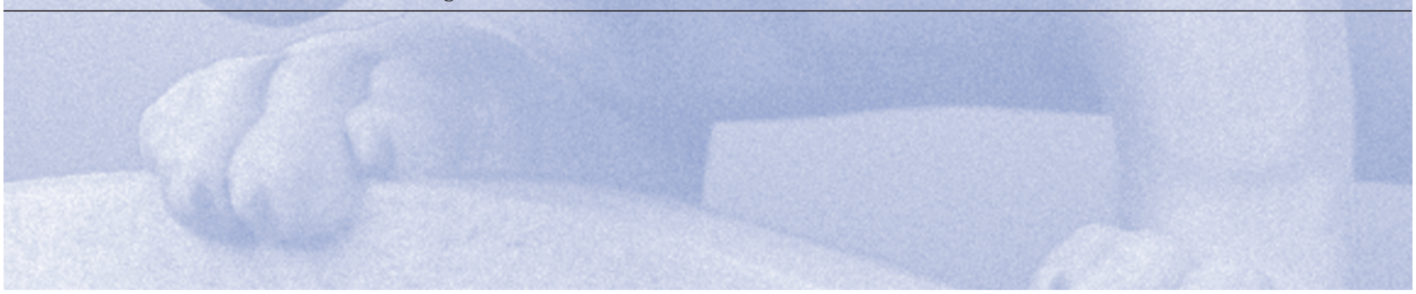
Major General Richard Kelly, USMC, the Vice Director for Logistics, J-4, The Joint Staff recently visited and toured iMAST facilities at ARL Penn State. General Kelly was able to visit numerous facilities where he received briefing on the various Navy ManTech programs underway at Penn State. As ARL Penn State addresses more issues relative to maintenance and repair, it is increasingly apparent what value this brings to the critical logistics effort necessary to support naval expeditionary warfare. The Applied Research Laboratory and Penn State's Center for Supply Chain Research (Smeals College of Business Administration) are working together to complement efforts that will reduce the length and size of the logistics "tail" necessary to support the forward-based warfighters.

Annual Report On-Line

The 2001 iMAST annual report is now on-line as a .pdf file. Visit our web site at <www.arl.psu.edu/areas/imast/imast.html>. A limited number of hard copies are also available upon request. First call—first serve.

CALENDAR OF EVENTS

11–14 March	DoD Logistics Conference		Jacksonville, FL
21–22 March	NDIA Combat Vehicle Conference		Ft. Knox, TN
26–28 March	Navy League Sea-Air-Space Expo		Washington, D.C.
3–4 April	Tech Trends 2002		Baltimore, MD
22-23 May	Materials and Manufacturing Advisory Board meeting		State College, PA
29–31 May	Johnstown Showcase for Commerce	★★★★★ *visit the iMAST booth*	Johnstown, PA
11–13 June	AHS Forum 58	★★★★★ *visit the iMAST booth*	Montreal, Canada
31 July–2 Aug	ARMTech Showcase		Kittanning, PA
Aug TBA	3rd Annual ONR Naval-Industry R&D Conference	★★★★★ *visit the iMAST booth*	Washington, DC
10–12 Sept.	ASNE Symposium		Bremerton, WA
17–19 Sept.	Marine Corps League Expo	★★★★★ *visit the iMAST booth*	Quantico, VA
Sept. TBA	NDIA Tracked Vehicle Conference		Ft. Knox, KY
Oct .TBA	Materials and Manufacturing Advisory Board meeting		State College, PA
21–24 Oct.	NDIA Expeditionary Warfare Conference		Panama City, FL
2–5 Dec.	Defense Manufacturing Conference 2002	★★★★★ *visit the iMAST booth*	Dallas, TX



Quotable

"There is no section titled: 'The Unfair Use of Technology' in the Geneva Convention."
— industry maxim

PENNSTATE
1855

Applied Research Laboratory
P.O. Box 30
State College, PA 16804–0030

Nonprofit Org.
U.S. Postage
PAID
University Park, PA
Permit No. 1

ADDRESS CORRECTION REQUESTED